Climate, Nutrients, and Hypoxia: Predicting Water Quality Trends in the Next 100 Years

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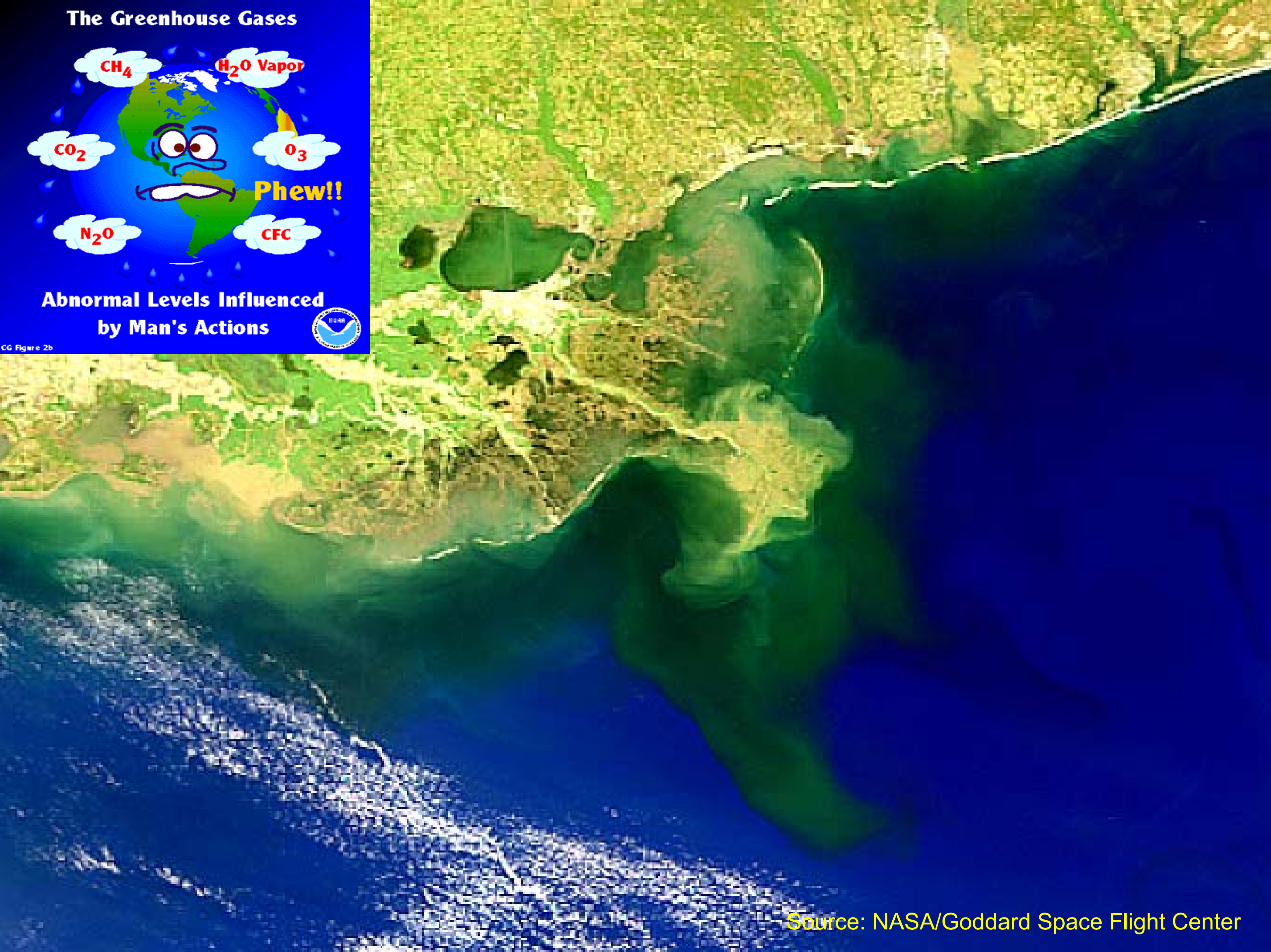
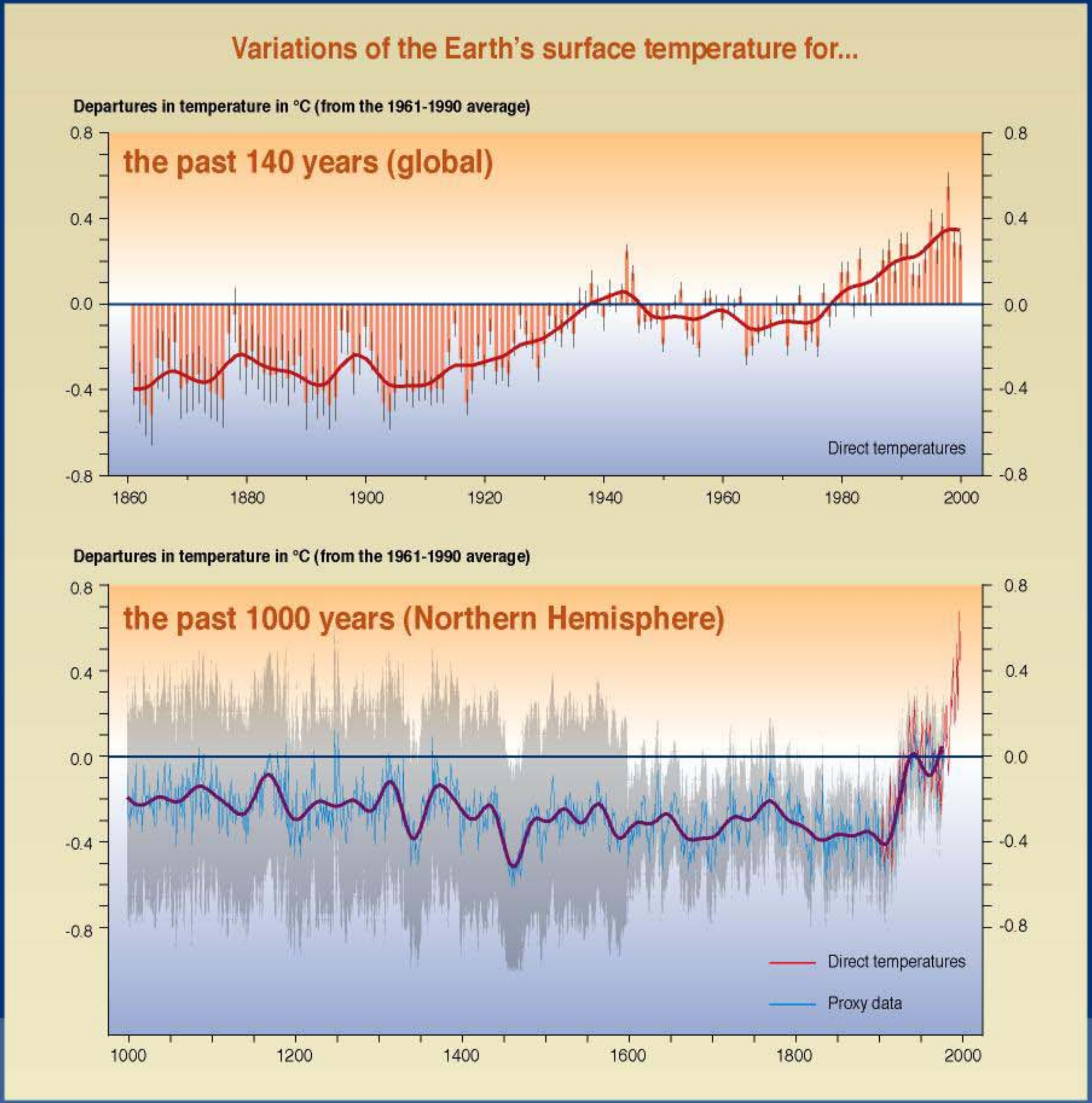


Source: NASA/Goddard Space Flight Center

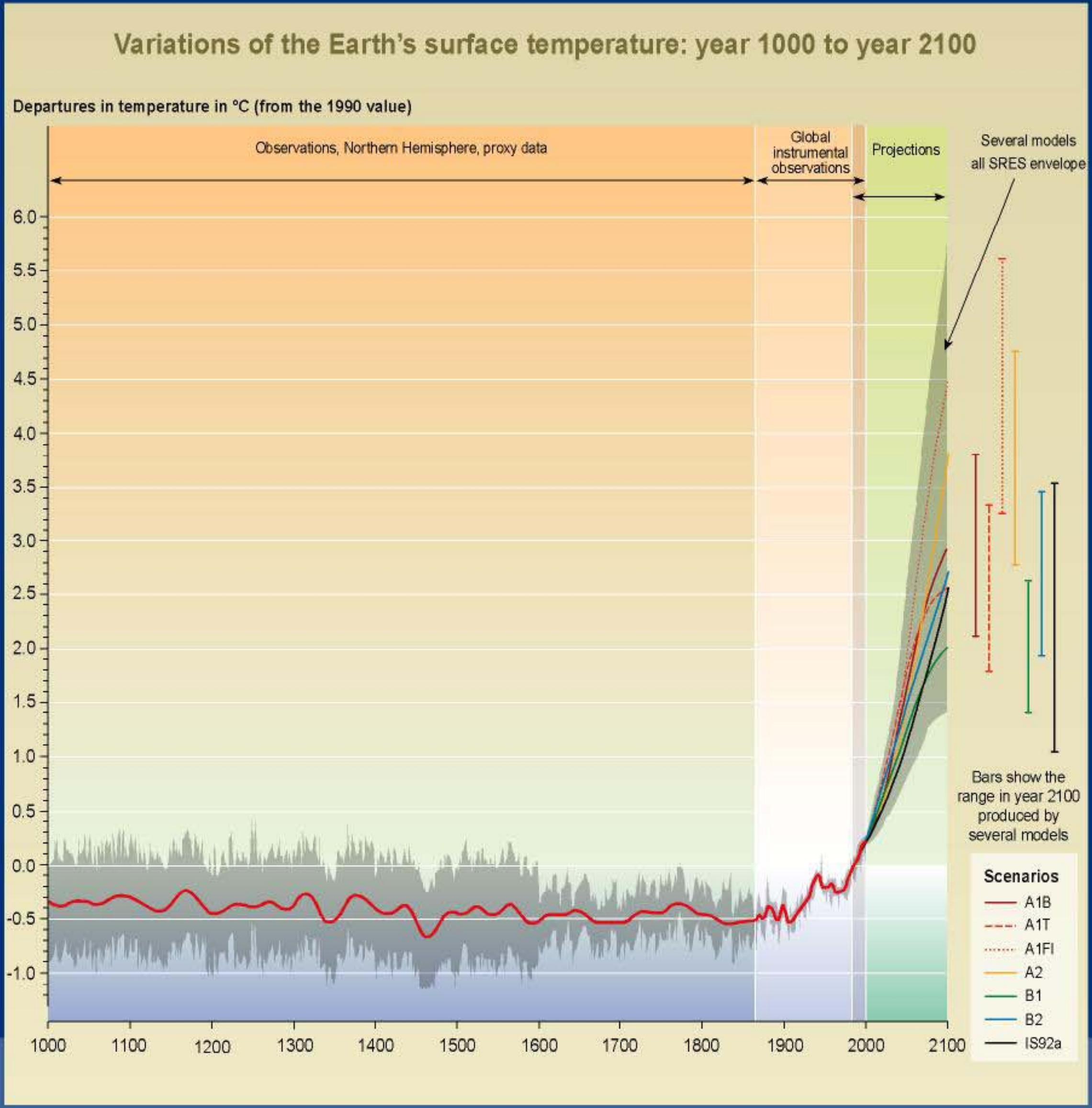
Sensitivity of the northern Gulf of Mexico to global climate change

- Dominated by discharges of one of the world largest rivers - the Mississippi River (drains 41% of the area of the contiguous 48 states);
- Coastal Louisiana's land loss rates are the highest in the U.S. (60 - 80% of the nation's total wetland loss);
- Supports one of the most valuable U.S. fisheries, exceeded only by the combined Pacific Coast and Alaska regions;
- Affected by tropical storms and hurricanes;
- Continental shelf of the northern Gulf of Mexico is the site of the largest and most severe coastal hypoxic ("dead") zone in the western Atlantic Ocean (> 22,000 km^2).

- How can GCC affect the northern Gulf of Mexico, and the hypoxic zone in particular?
- What can we do about it?

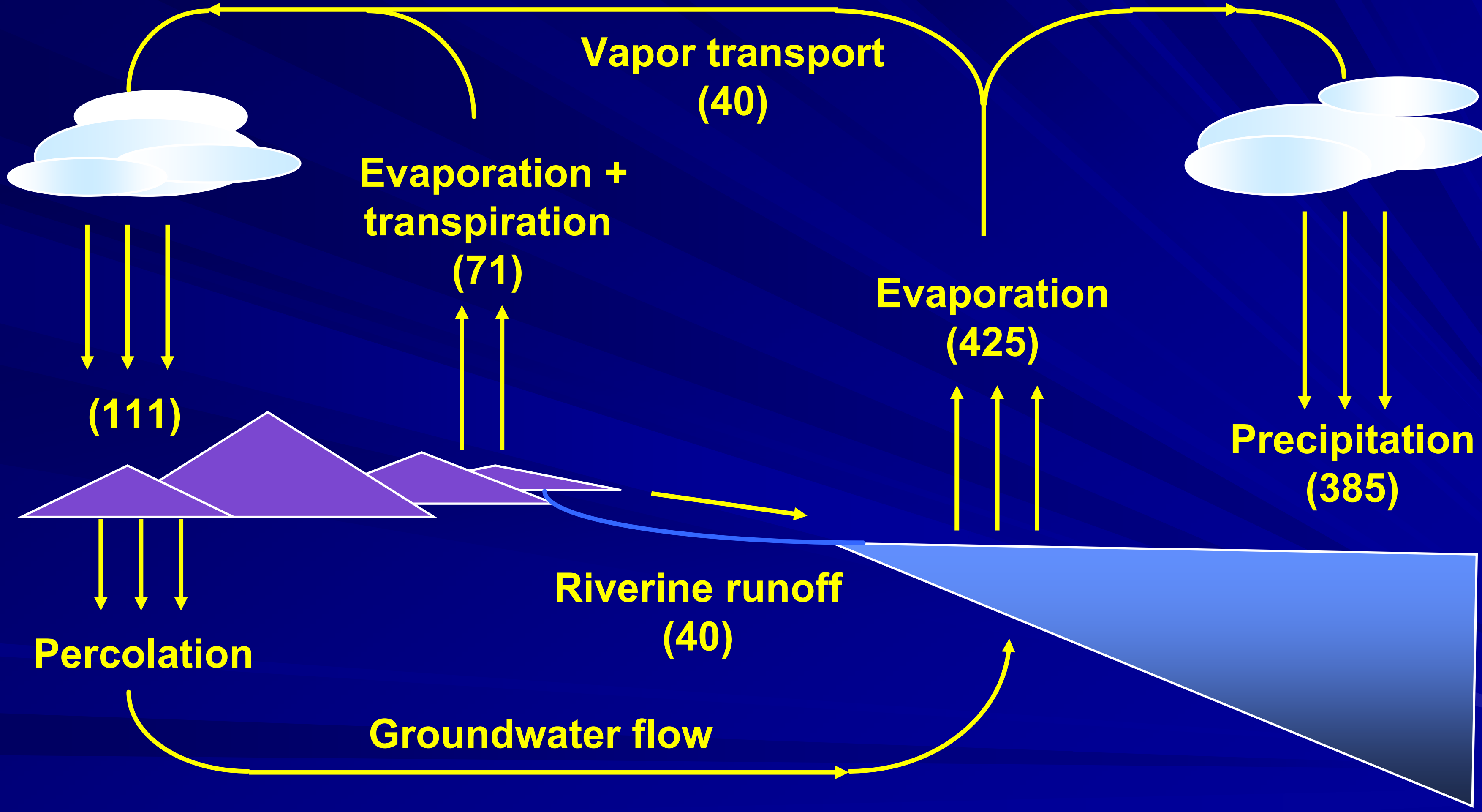


SYR - FIGURE 2-3

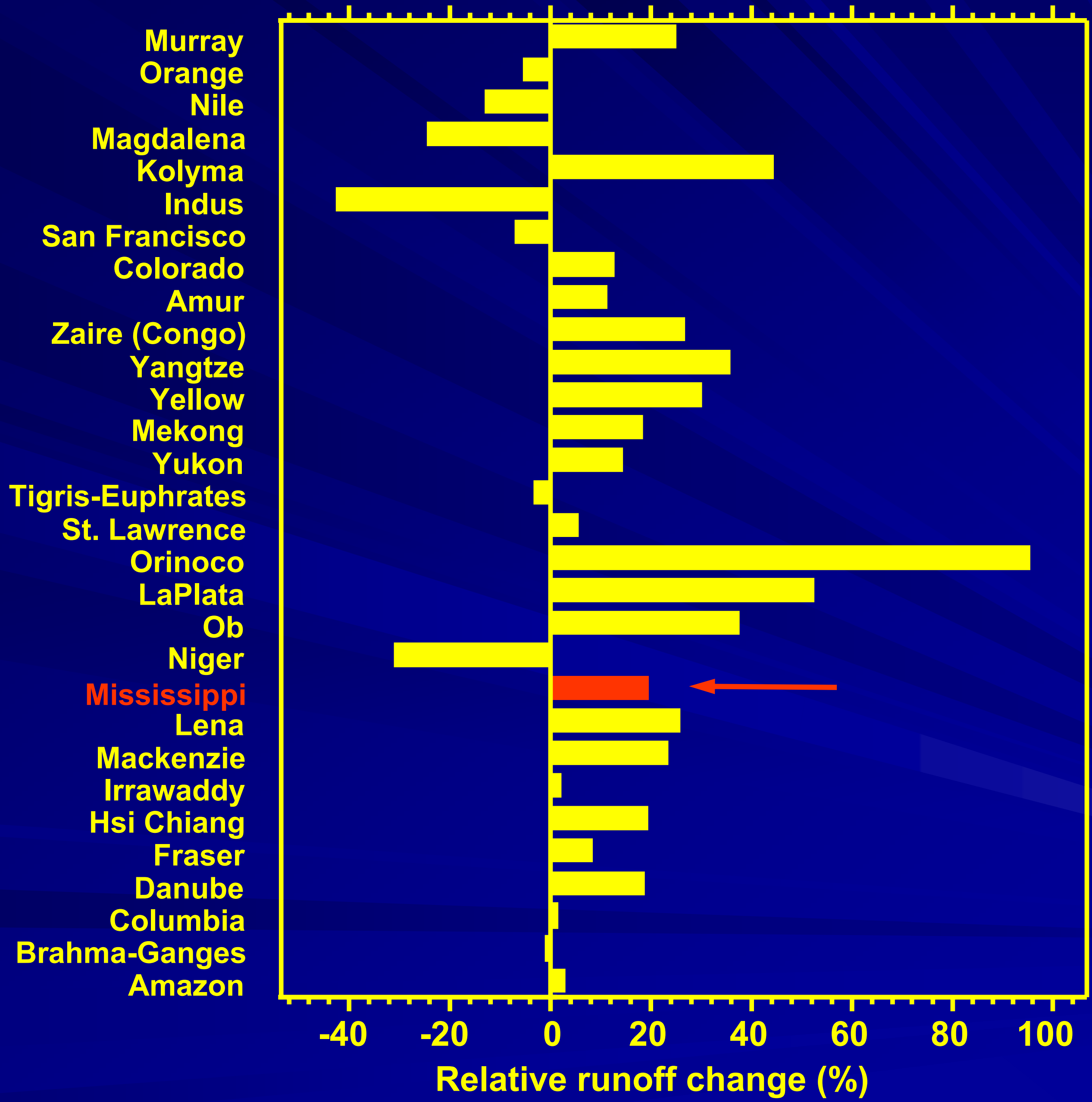


SYR - FIGURE 9-1b

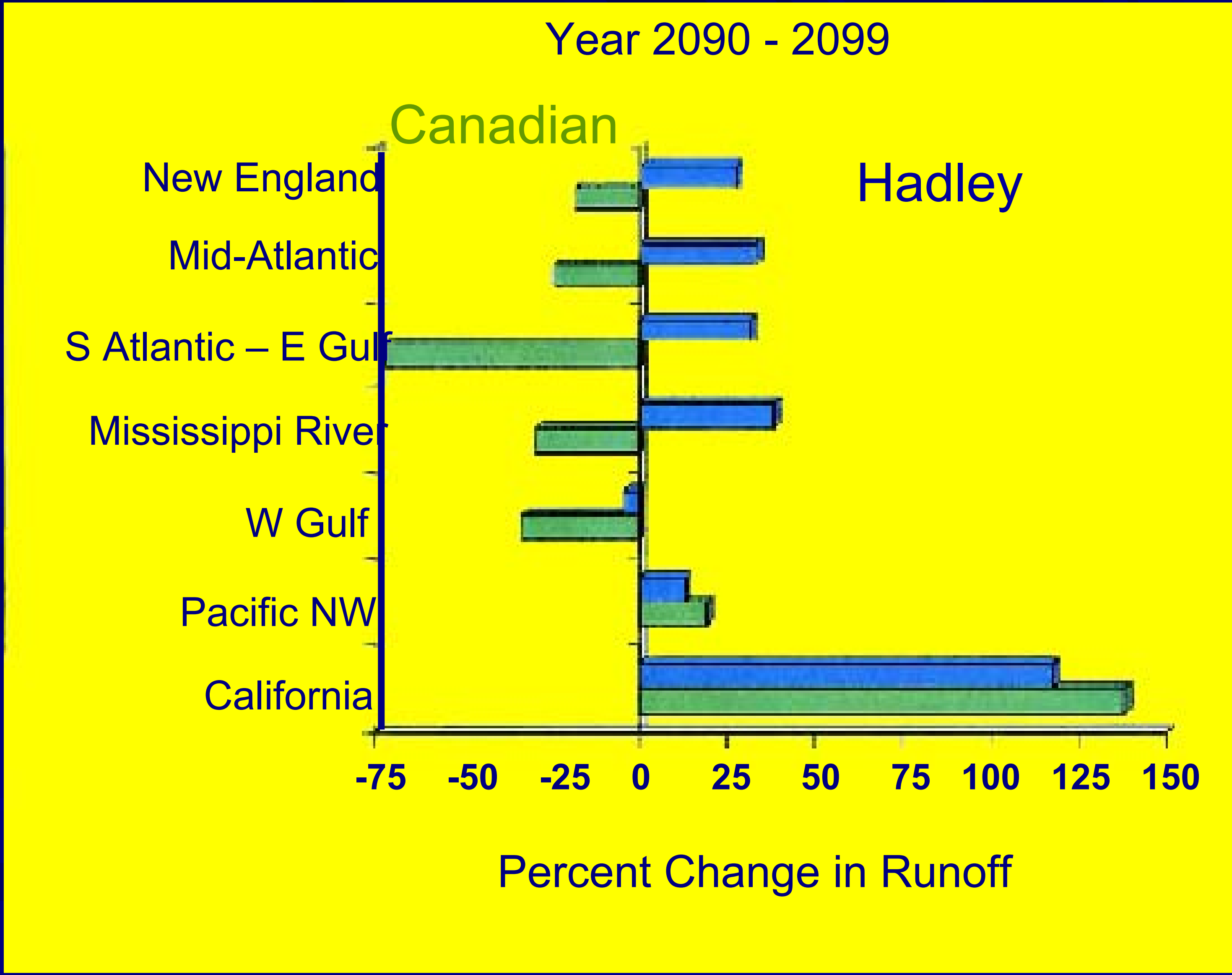
Global water cycle
(10^3 km^3 yr^{-1})



Projected $2xCO_2$ runoff



(adapted from Miller & Russell, 1992)

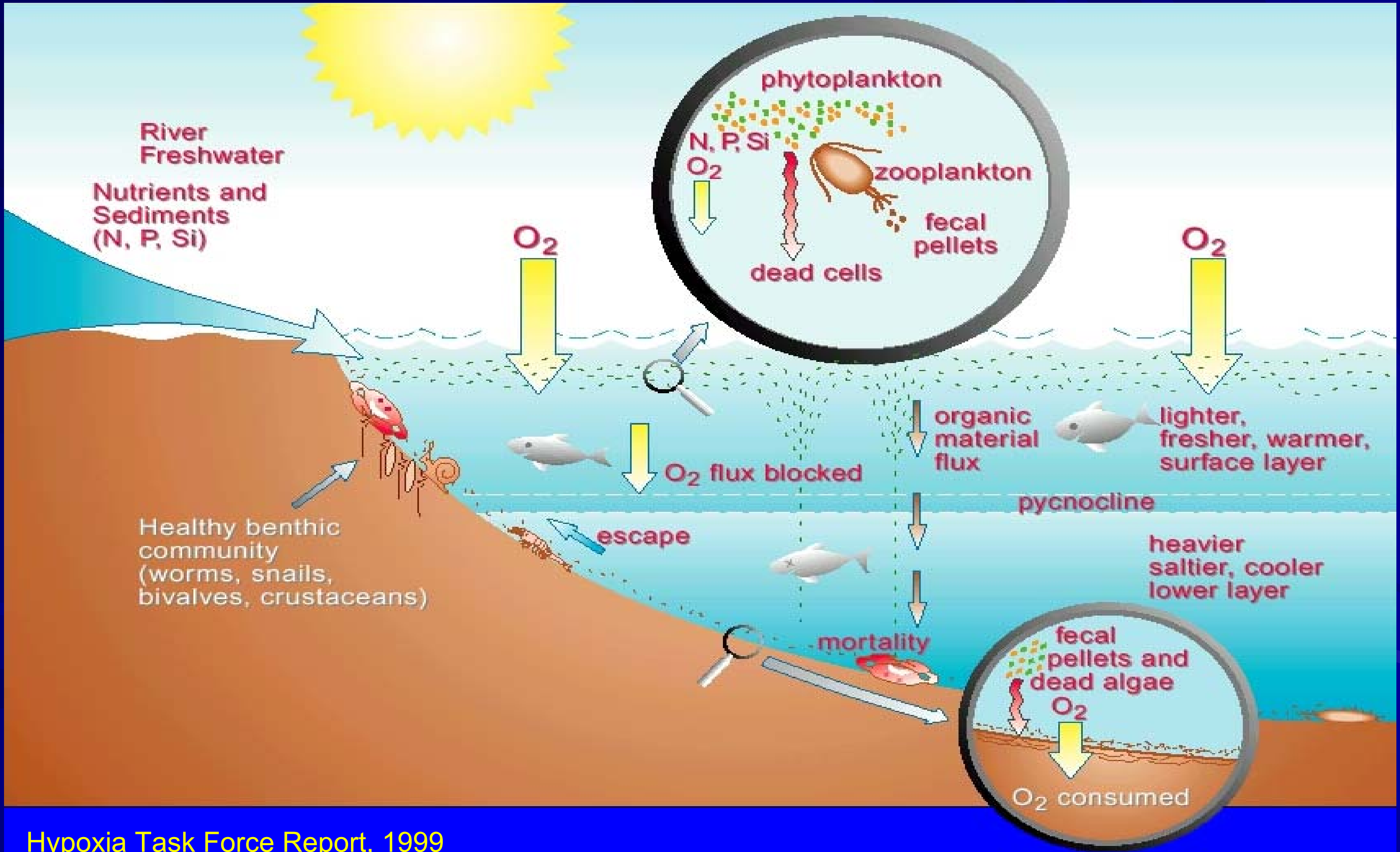


(Wolock and McCabe, 1999)

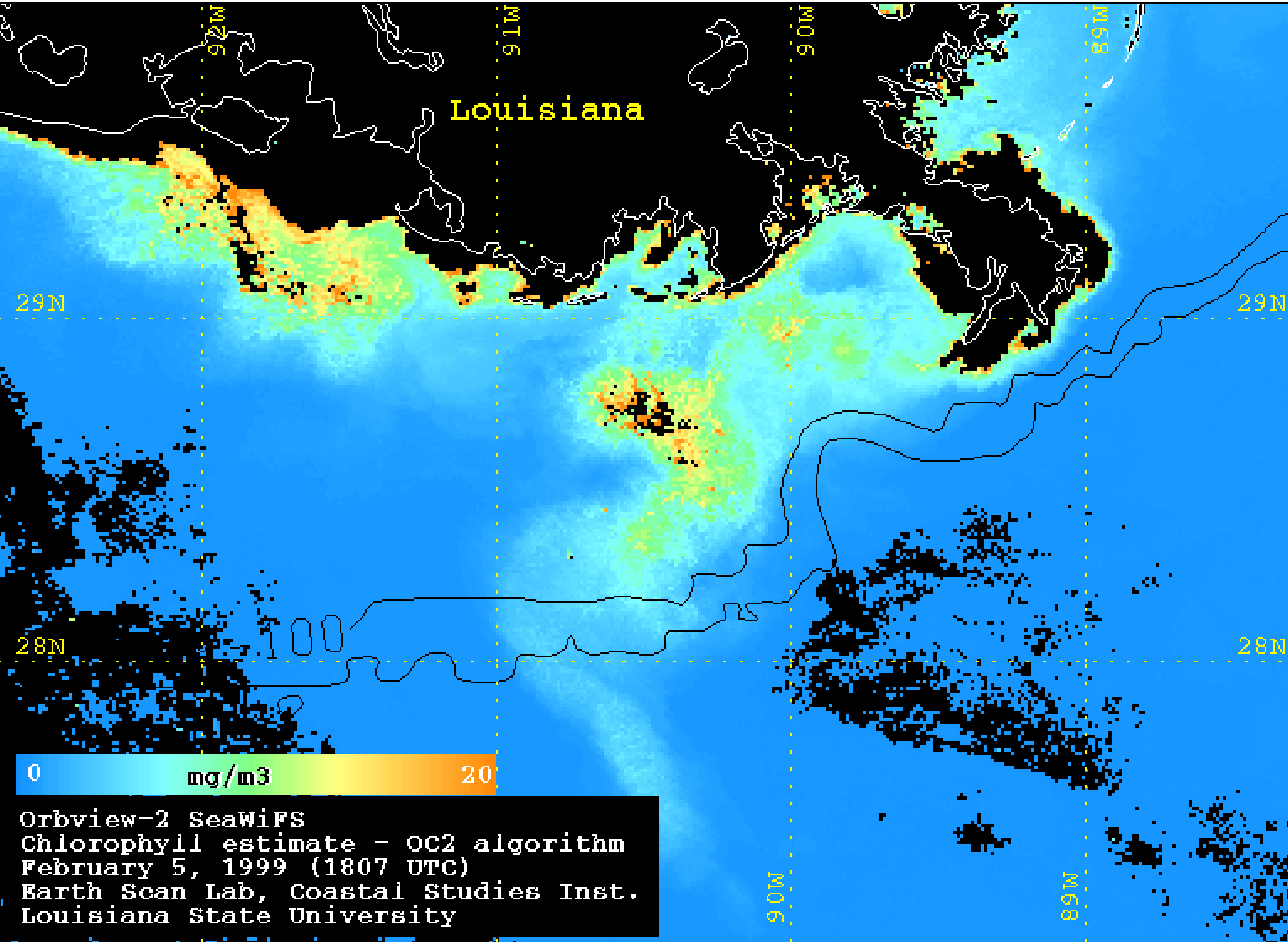
FIG. E.S. 1 Mississippi-Atchafalaya River Basin and Gulf Hypoxic Zone

Source: Donald Goolsby and William Battaglin, U.S. Geological Survey.

How Hypoxia develops



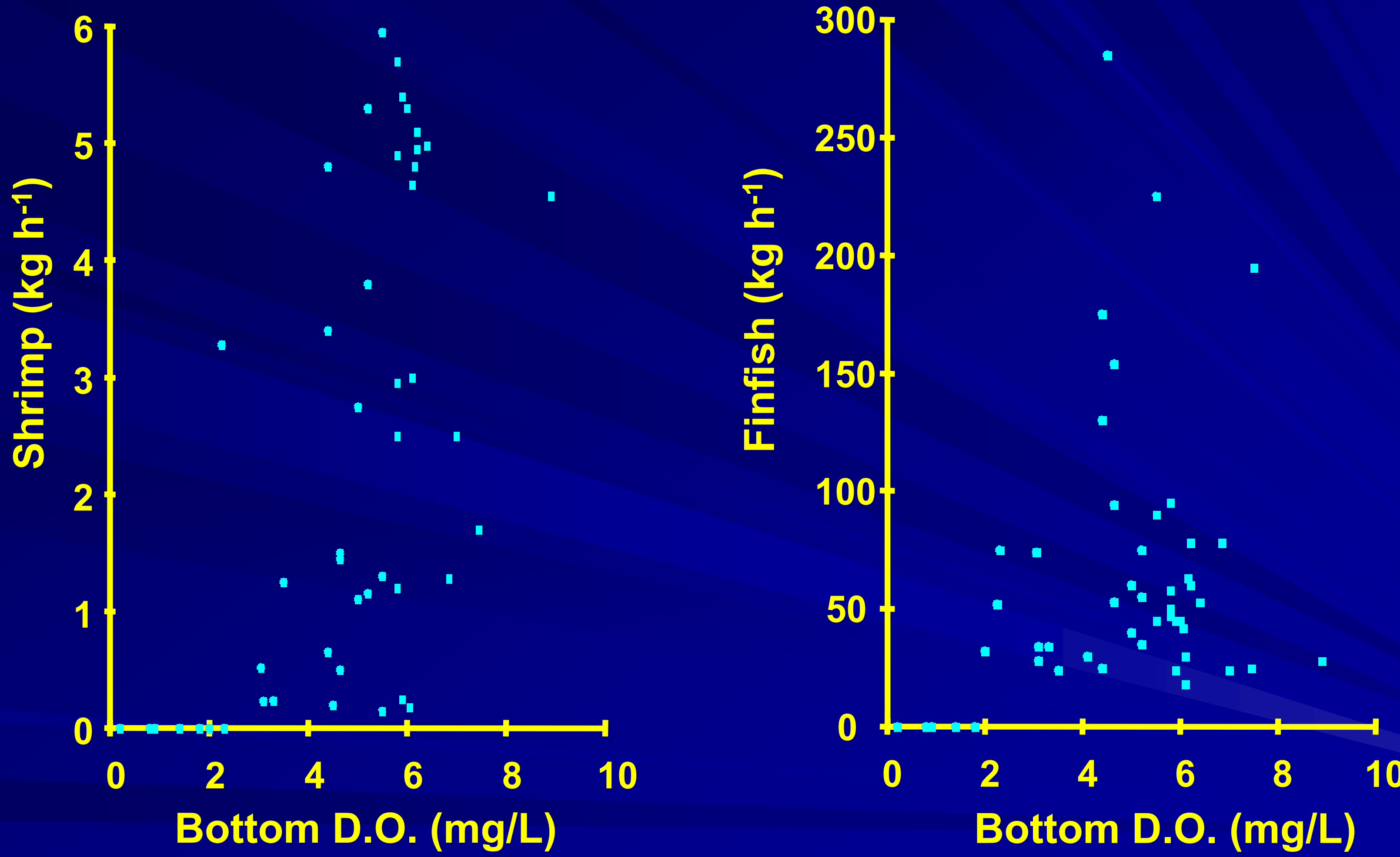
Hypoxia Task Force Report, 1999



92W
91W
90W
89W
Louisiana
29N
29N
28N
28N
100
0
mg/m3
20
Orbview-2 SeaWiFS
Chlorophyll estimate - OC2 algorithm
February 5, 1999 (1807 UTC)
Earth Scan Lab, Coastal Studies Inst.
Louisiana State University
90W
89W

G. Müller-Niklas, 1997.

Hypoxia = Dissolved O_2 < 2 mg/L (=2 ppm)



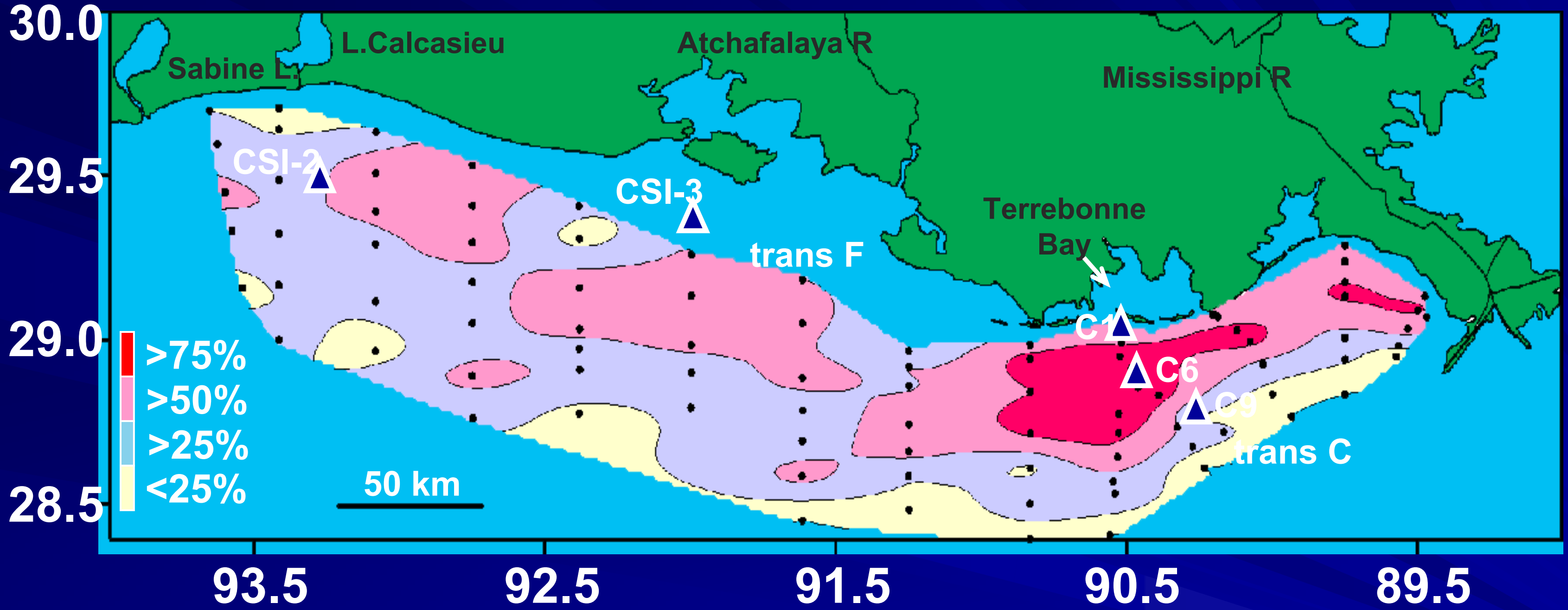
Data from Leming and Stuntz, 1984; SW Louis. Coast, June 1982

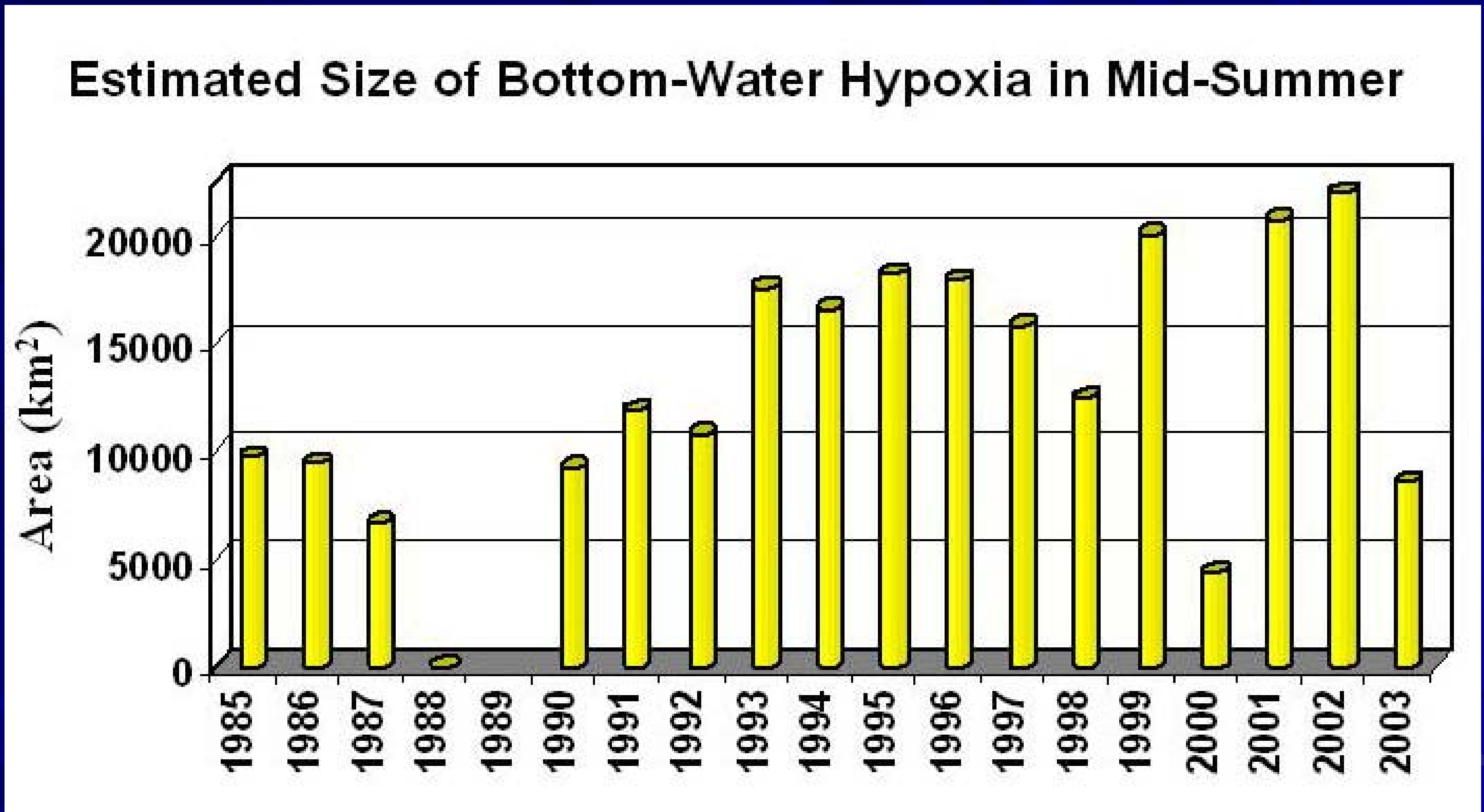
Photograph by Kerry St.Pe, LADEQ

If you cannot breathe,
nothing else matters.

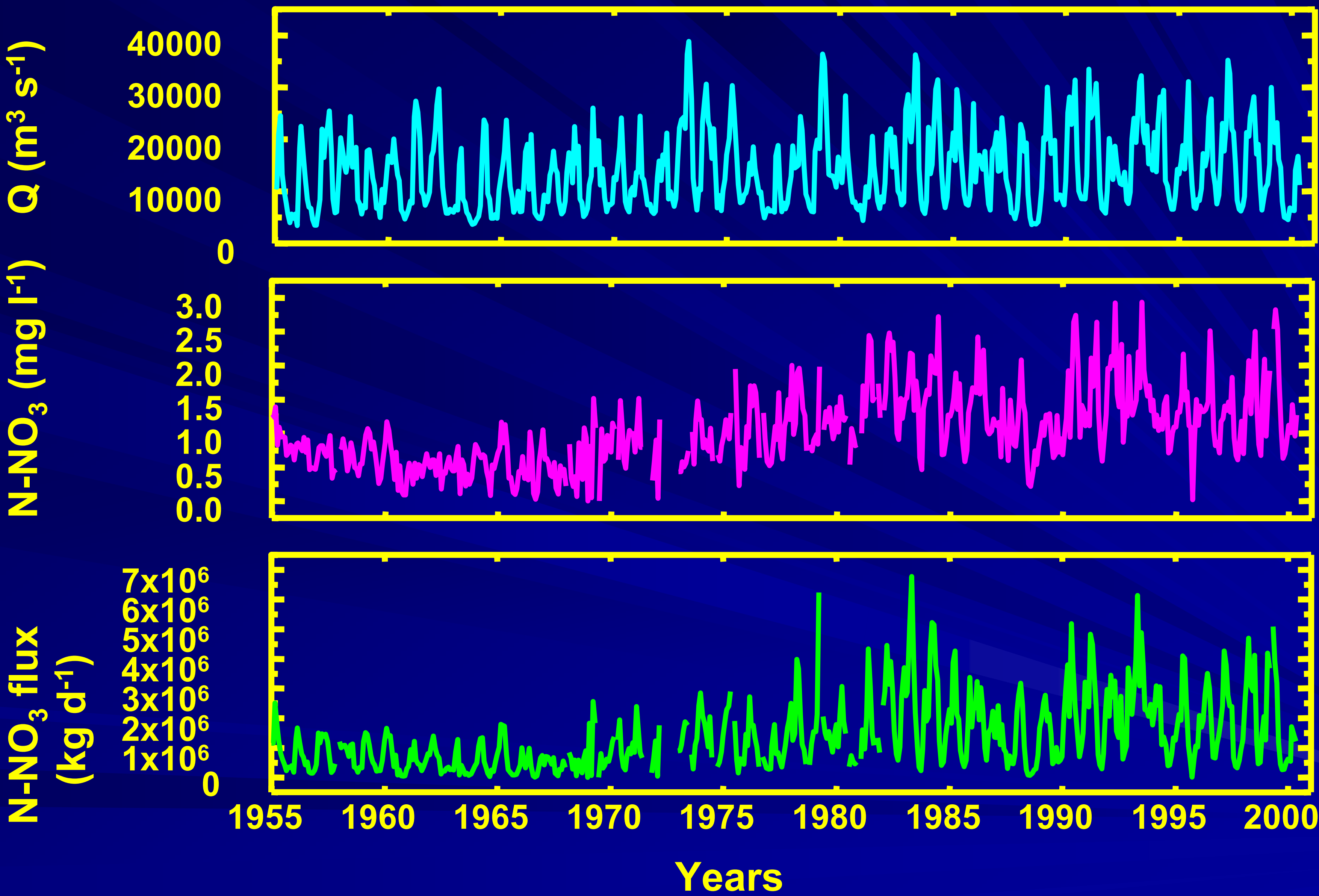
(American Lung Association)

Occurrence of mid-summer hypoxia 1985-2001 (Source: N. Rabalais, LUMCON)





N. Rabalais, LUMCON

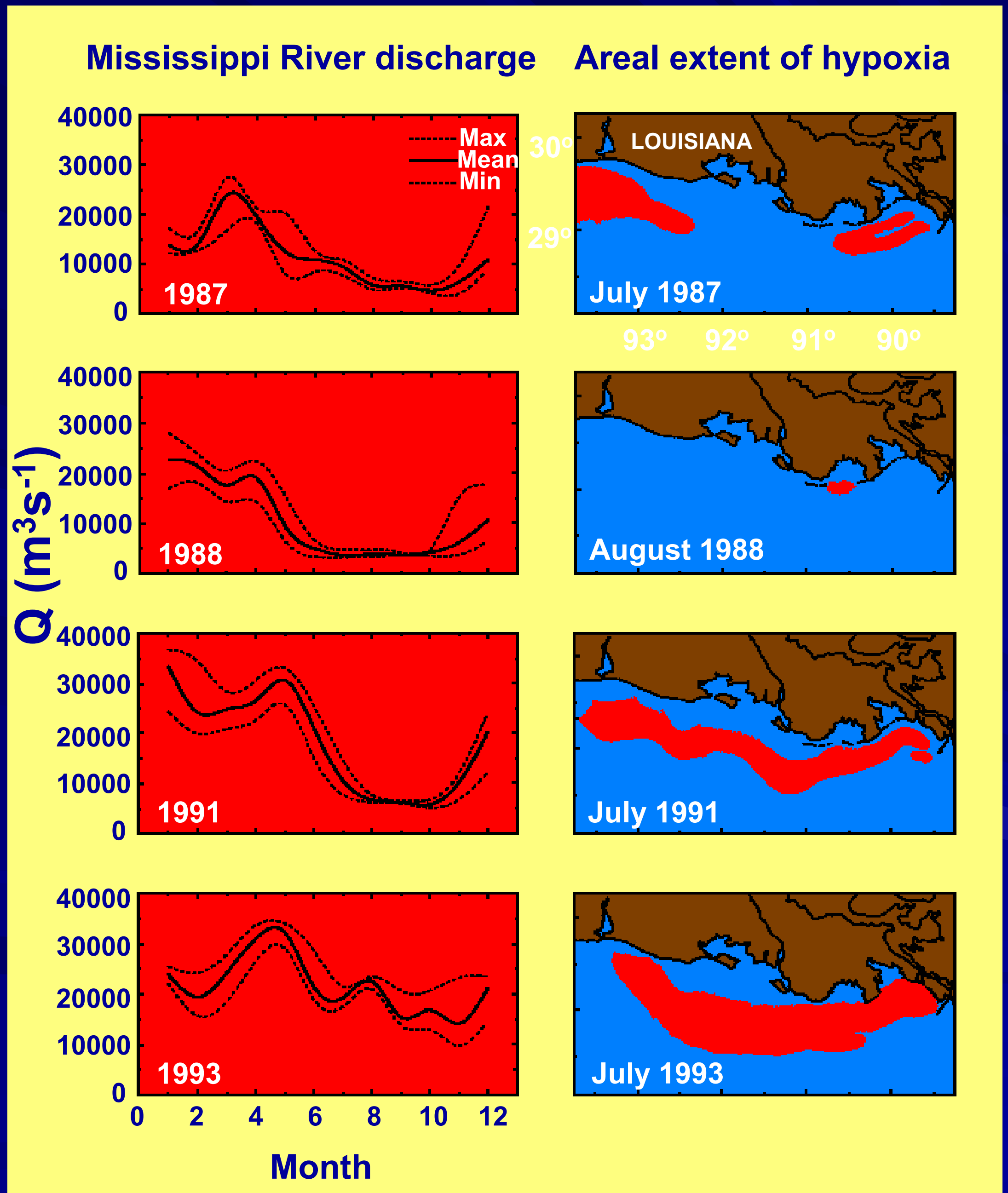


Justic et al., 2002

Trends in the Mississippi River Runoff, Nitrate Concentration, and Nitrate Flux 1954-2000

Period	Q ($m^3\ s^{-1}$)	N-NO_3 ($mg\ l^{-1}$)	N-NO_3 flux ($kg\ d^{-1}$)
1983-00	x=15,874 SD=7,908 n=209 ($p<0.01$)	x=1.37 SD=0.55 n=208 ($p<0.001$)	x=2,01x10^6 SD=1.36x10^6 n=208 ($p<0.001$)
1968-82	x=13,849 SD=7,104 n=180 ($p<0.001$)	x=1.05 SD=0.49 n=153 ($p<0.001$)	x=1,34x10^6 SD=0.99x10^6 n=153 ($p<0.001$)
1954-67	x=11,381 SD=6,359 n=161 ($p<0.001$)	x=0.61 SD=0.28 n=160 ($p<0.001$)	x=0.63x10^6 SD=0.49x10^6 n=160 ($p<0.001$)

Coupling between river flow and hypoxia

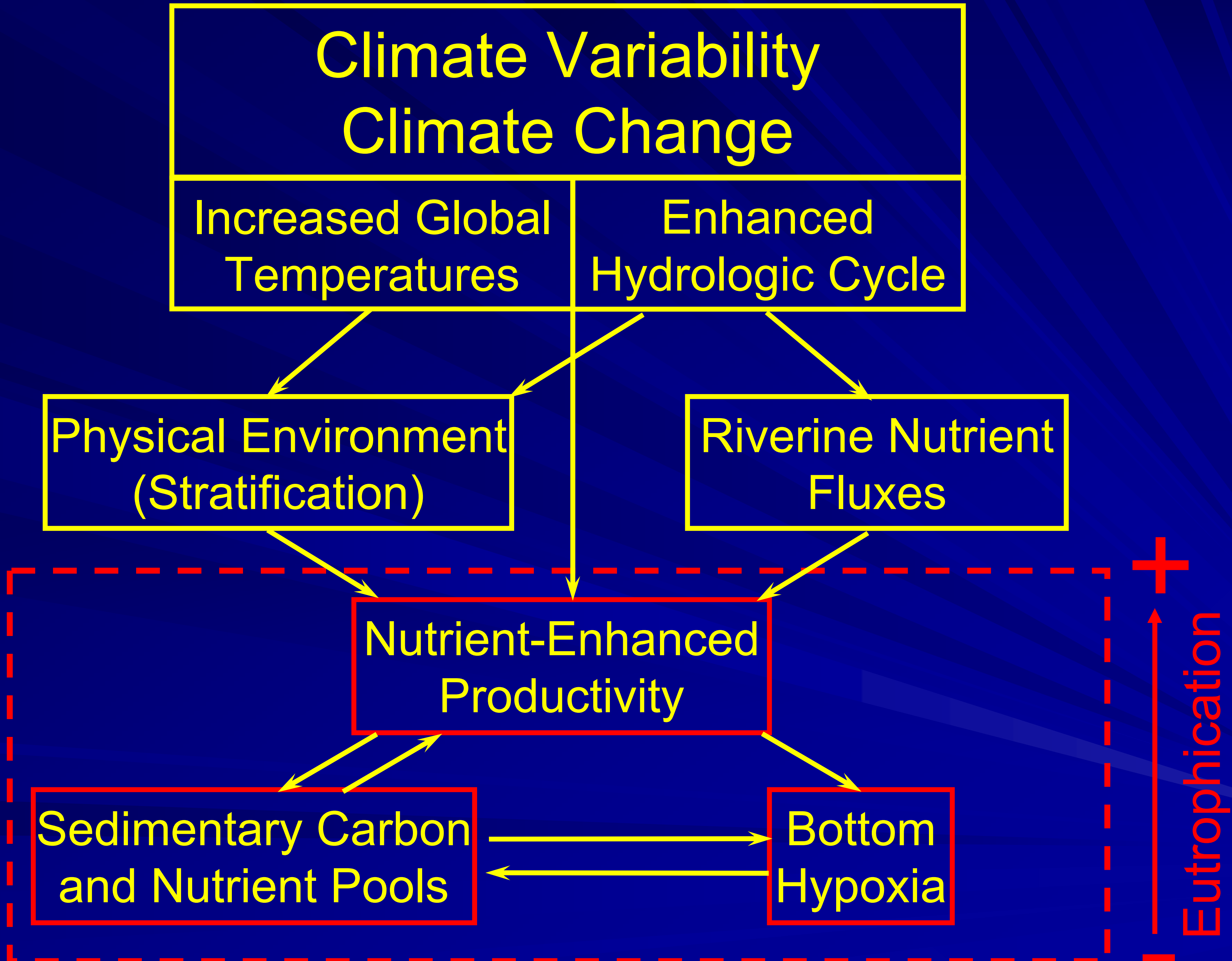


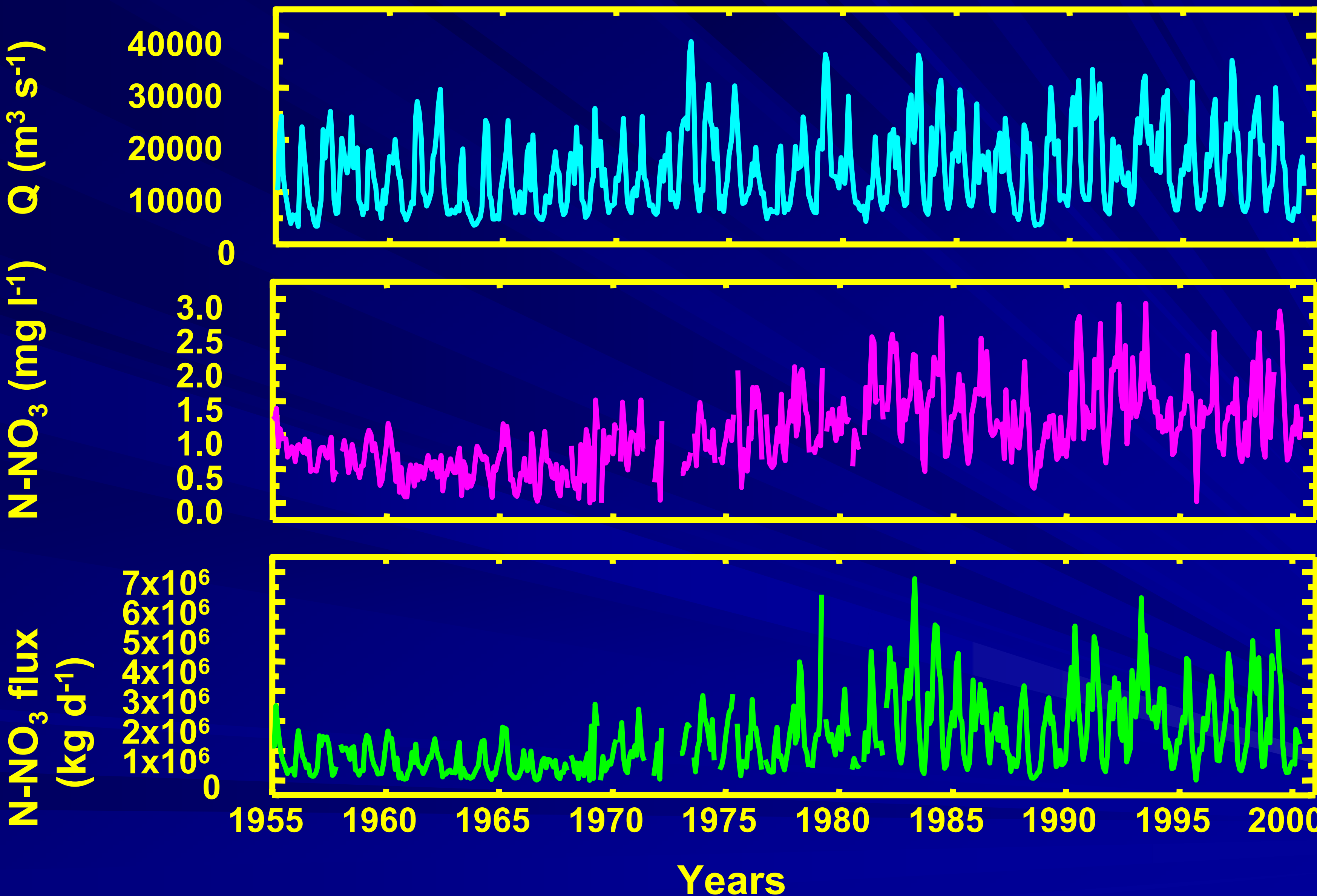
Justic et al., 1996

What will happen in the next 100 years?

Prediction is very difficult, especially about the future

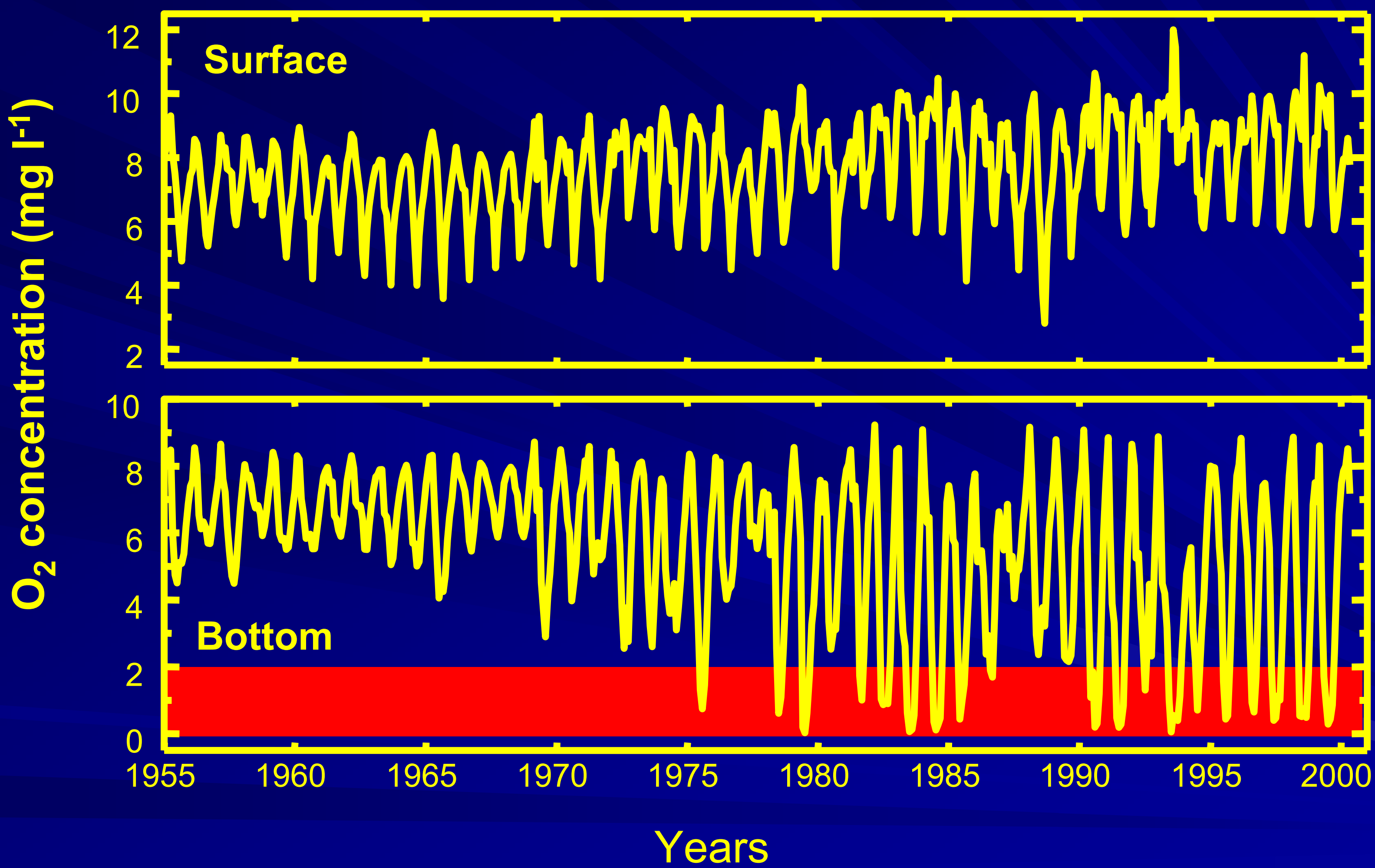
(Niels Bohr)


Climate Variability
Climate Change
Increased Global Temperatures
Enhanced Hydrologic Cycle
Physical Environment (Stratification)
Riverine Nutrient Fluxes
Nutrient-Enhanced Productivity
Sedimentary Carbon and Nutrient Pools
Bottom Hypoxia
+
Eutrophication
-

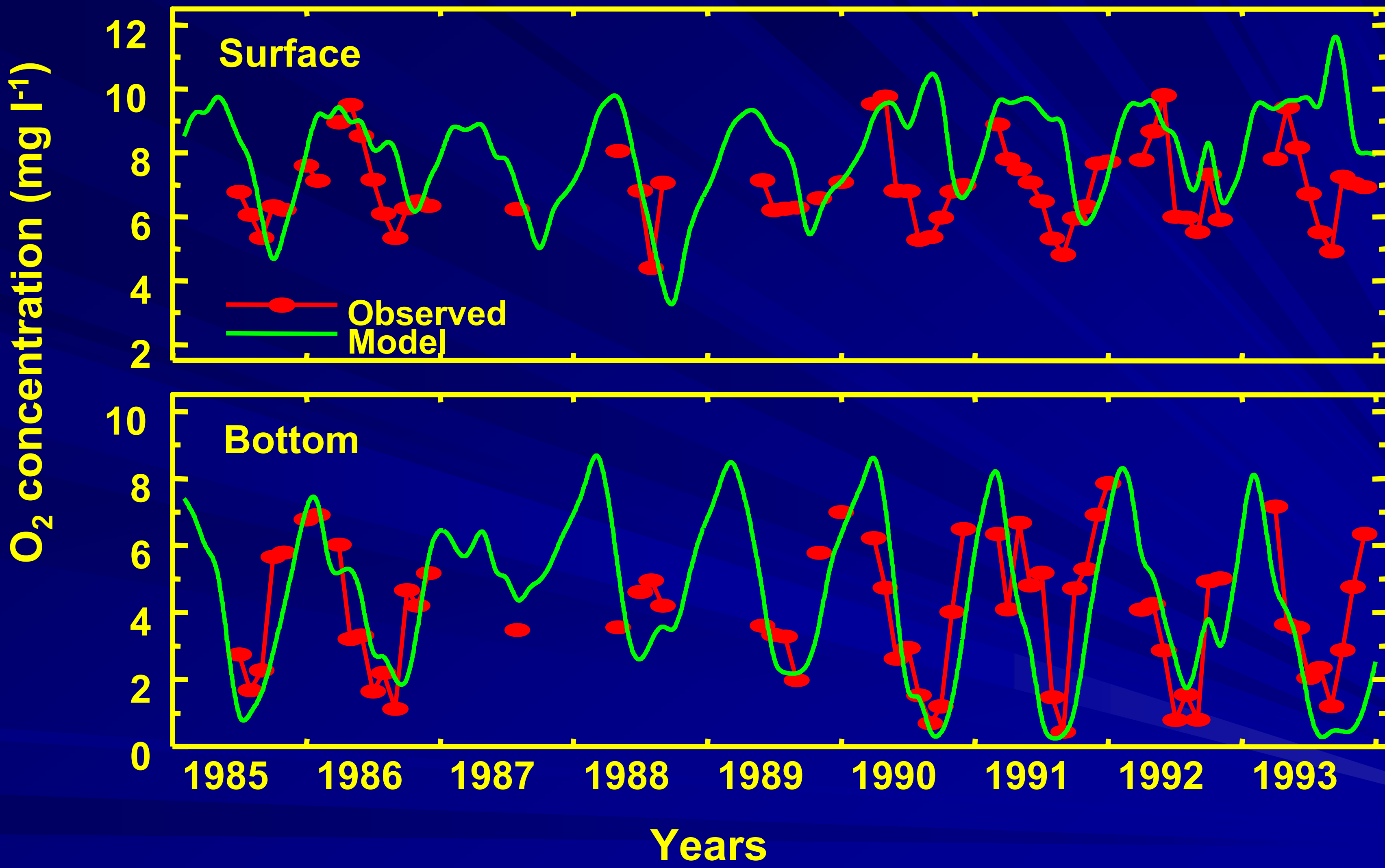


Justic et al., 2002

Nominal model



Justic et al., 2002

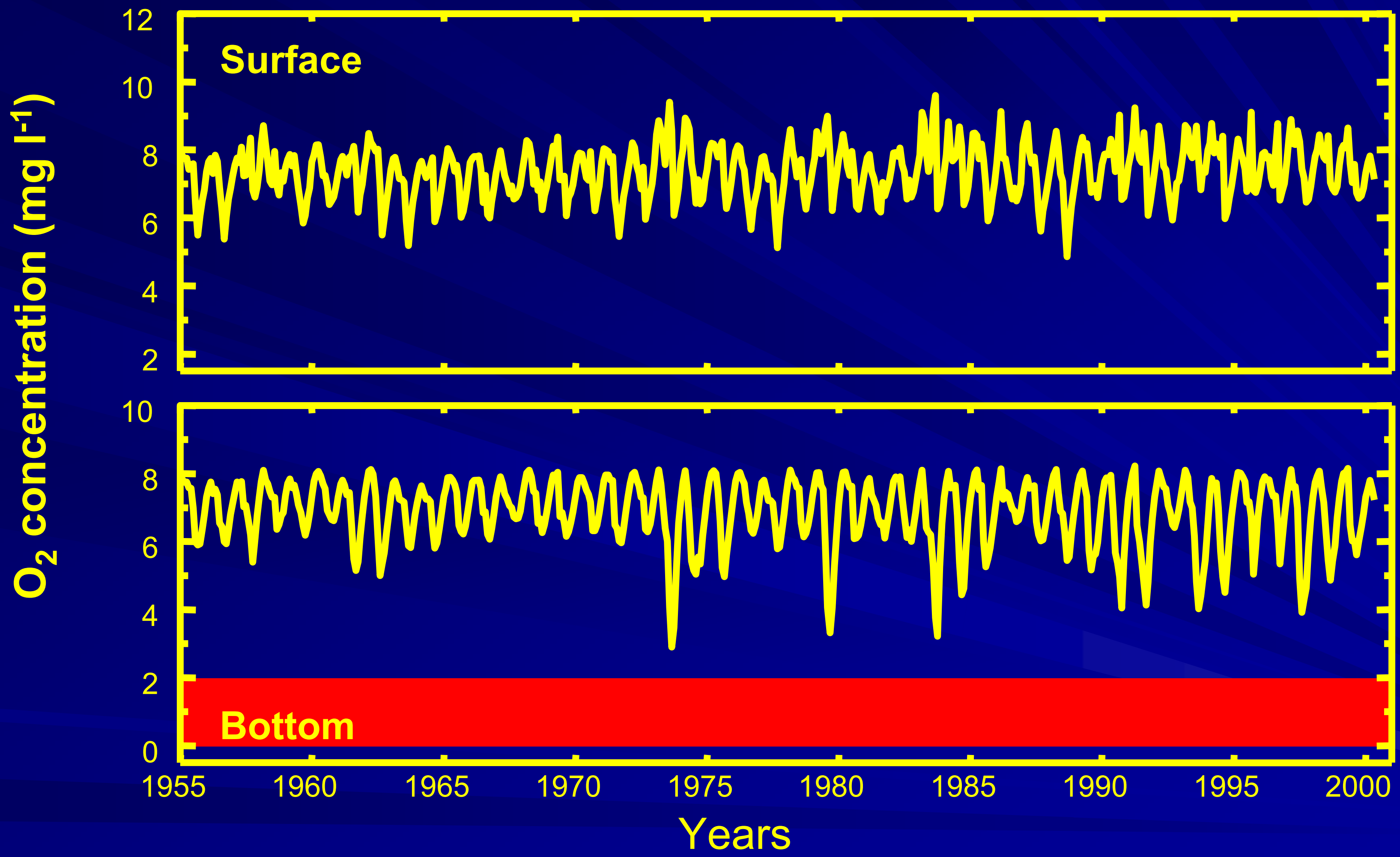


Justic et al., 2002

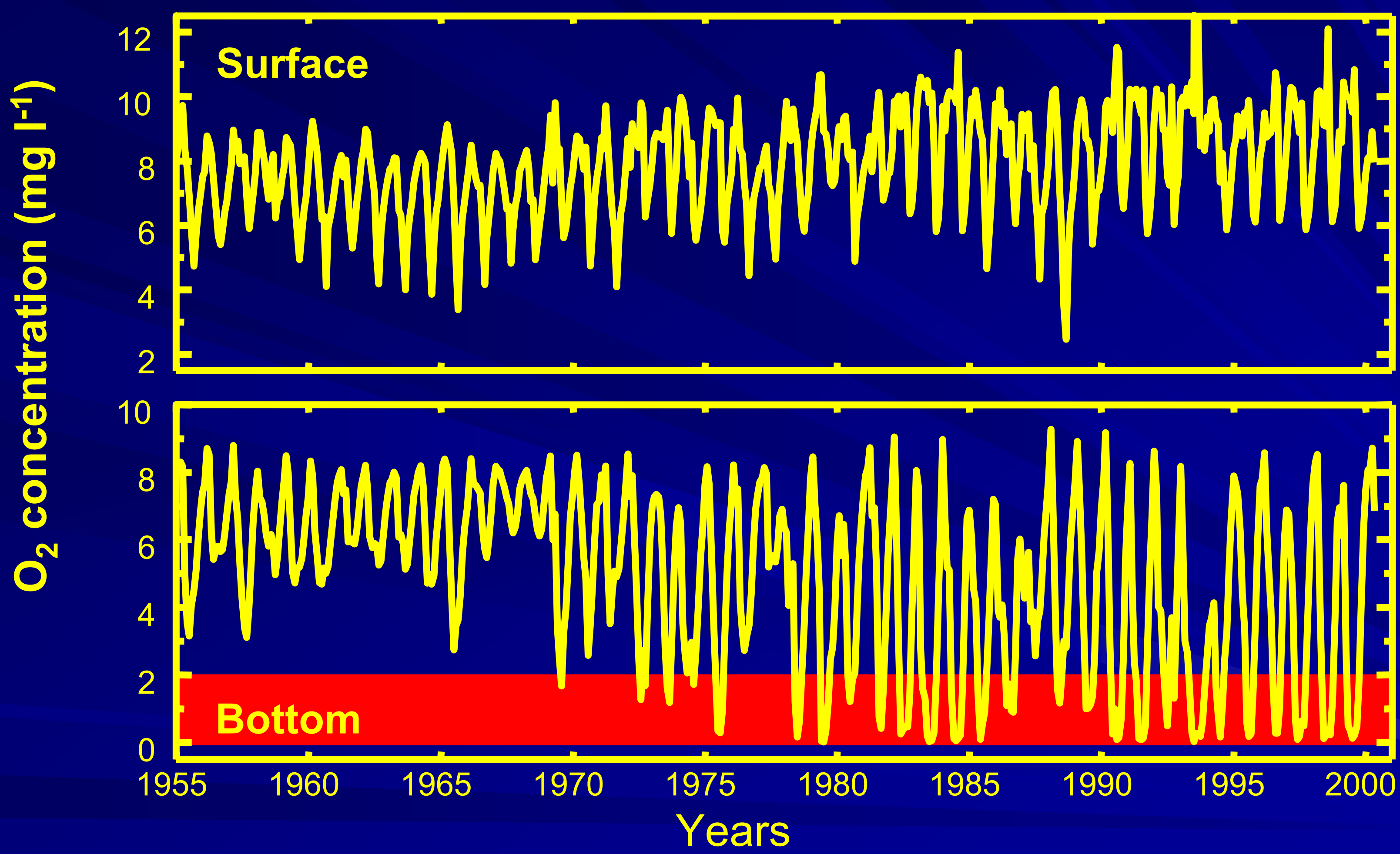
Model Scenarios

- 30% reduction in MR runoff (Wolock and McCabe, 1999)
- MR nitrate concentration unchanged with respect to 1954 –1967
- 20% increase in MR runoff (Miller and Russell, 1992)
- 4 ^{o}C increase in NGM temperature (IPCC, 2001)
- 20% increase in MR runoff + 4 ^{o}C increase in NGM temperature (likely GCC scenario; IPCC, 2001)
- 30% reduction in MR nitrate flux (proposed management action; Rabalais et al., 2002)

MR nitrate 1954-1967

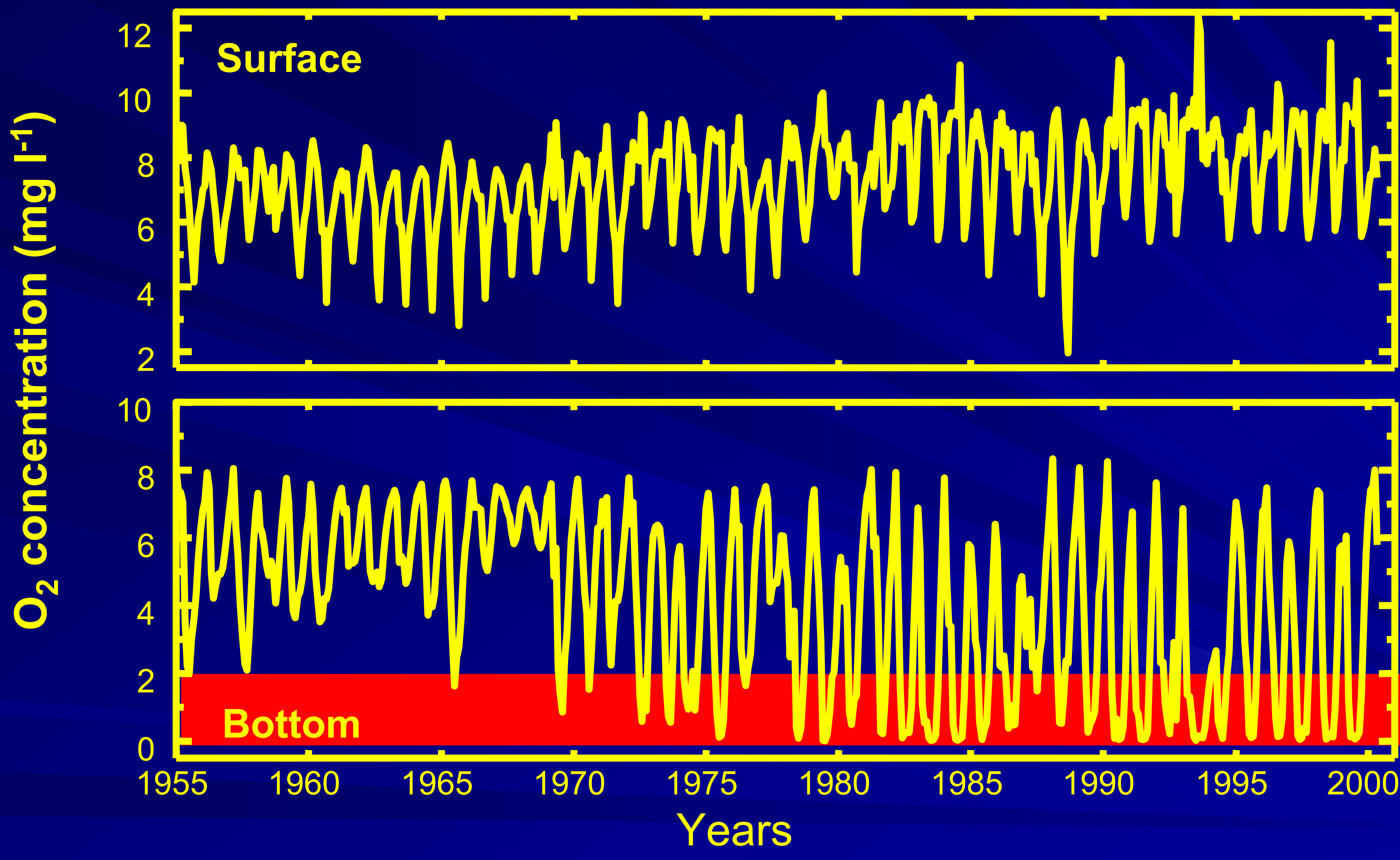


+20% MR runoff

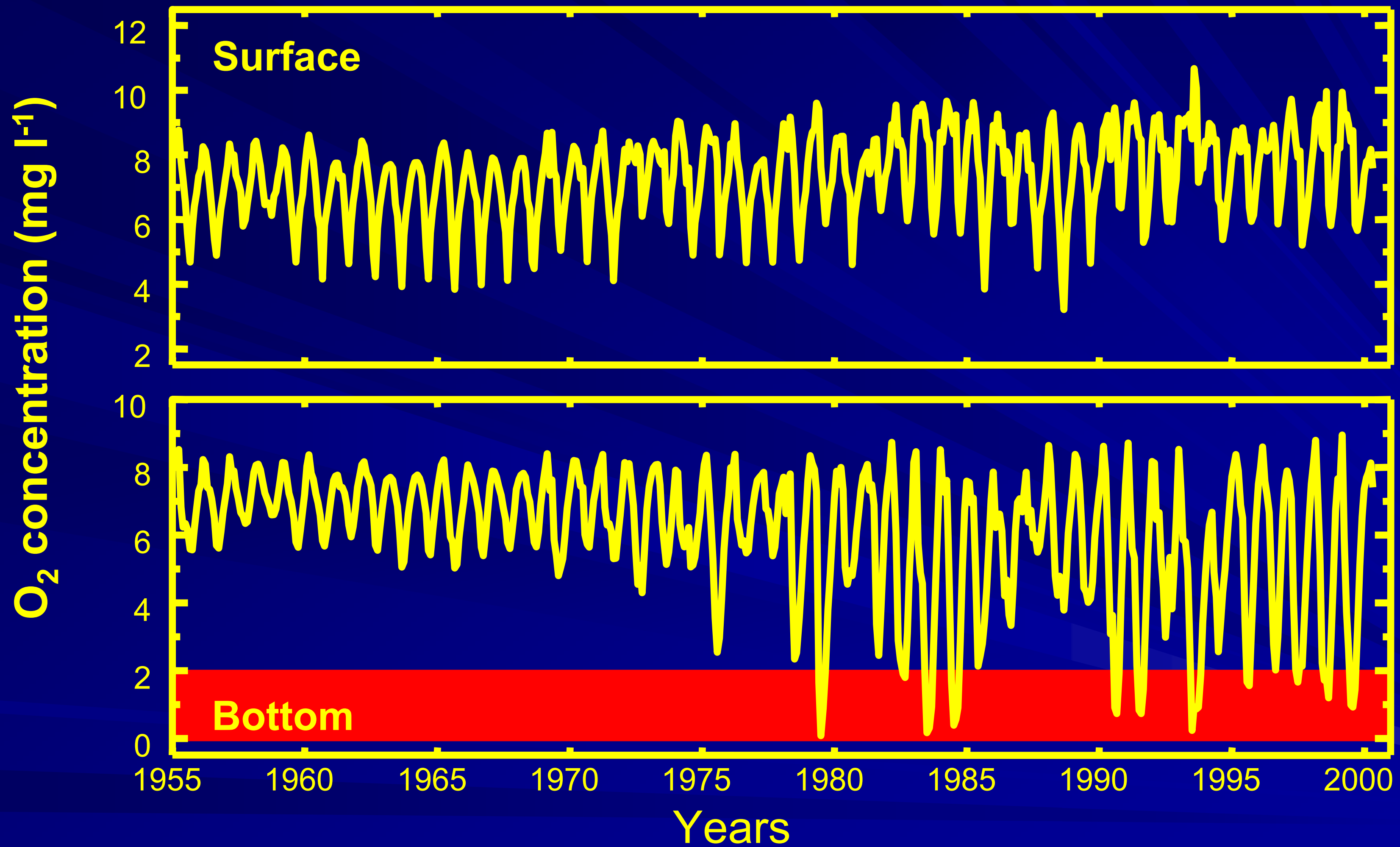


Surface
Bottom
O2 concentration (mg l-1)
12
10
8
6
4
2
0
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Years

+20% MR runoff +4oC



-30% MR nitrate flux



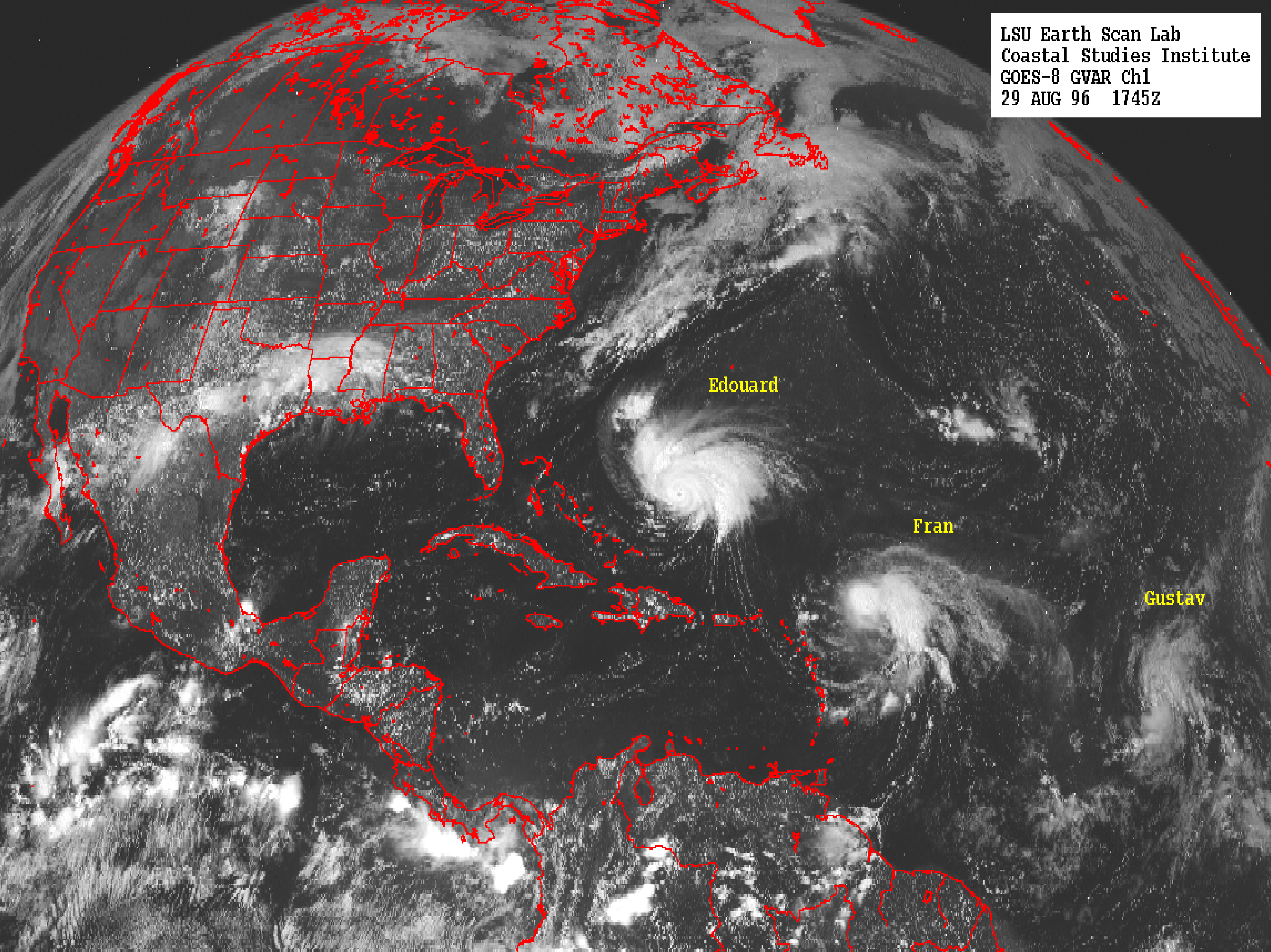
Model Results

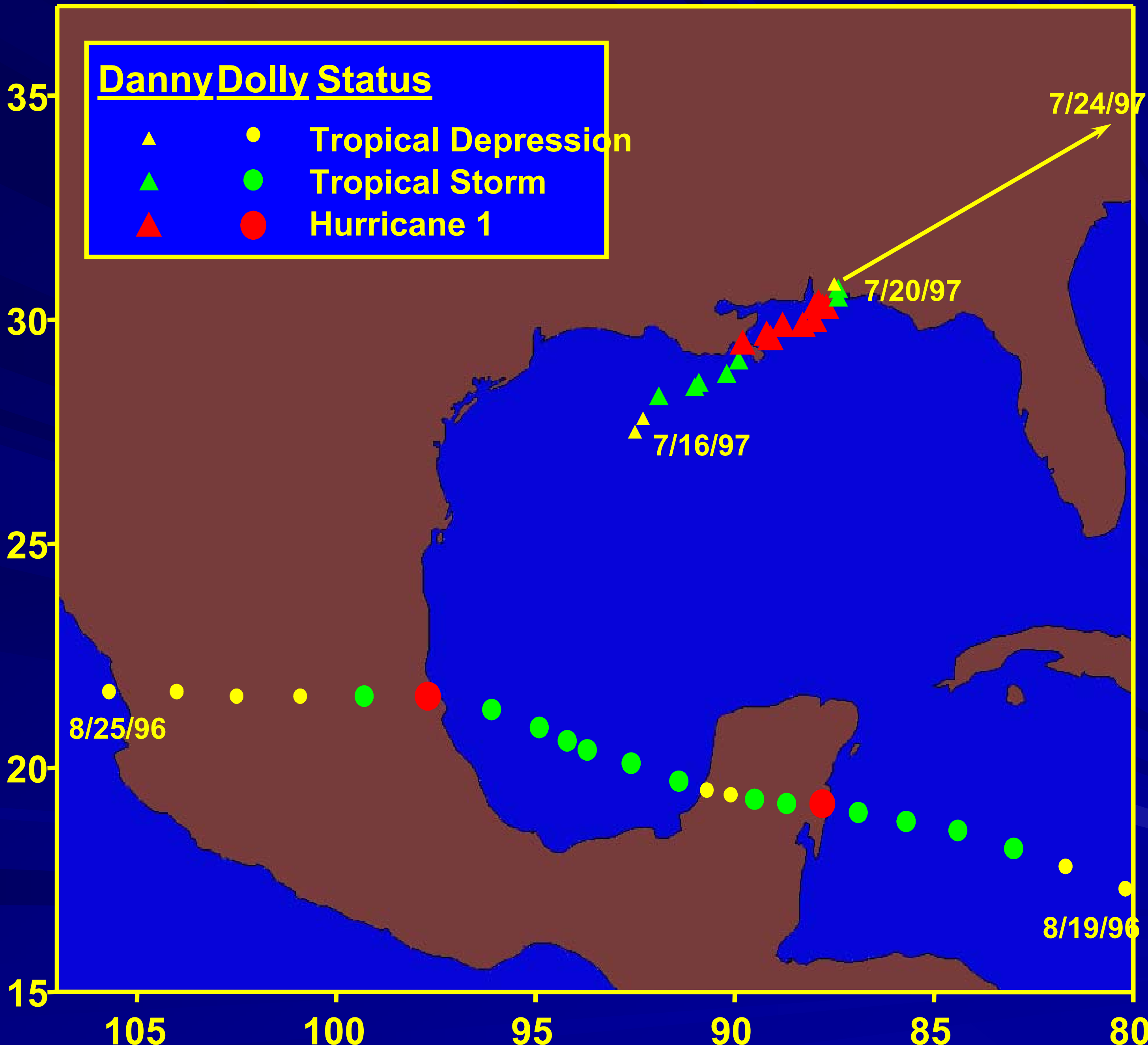
Scenario	YWMH (< 2 mg/l)	YWSH (< 1 mg/l)	% Change
1. Nominal model	19	16	-
2. -30% MR runoff	8	4	-58
3. MR nitrate 1954-1967	0	0	∞
4. +20% MR runoff	26	20	+37
5. +4 ^{o}C	25	19	+32
6. +20% MR runoff +4 ^{o}C	31	26	+63
7. -30% MR nitrate flux	12	7	-37

The total number of years = 45

Justic et al., 2003

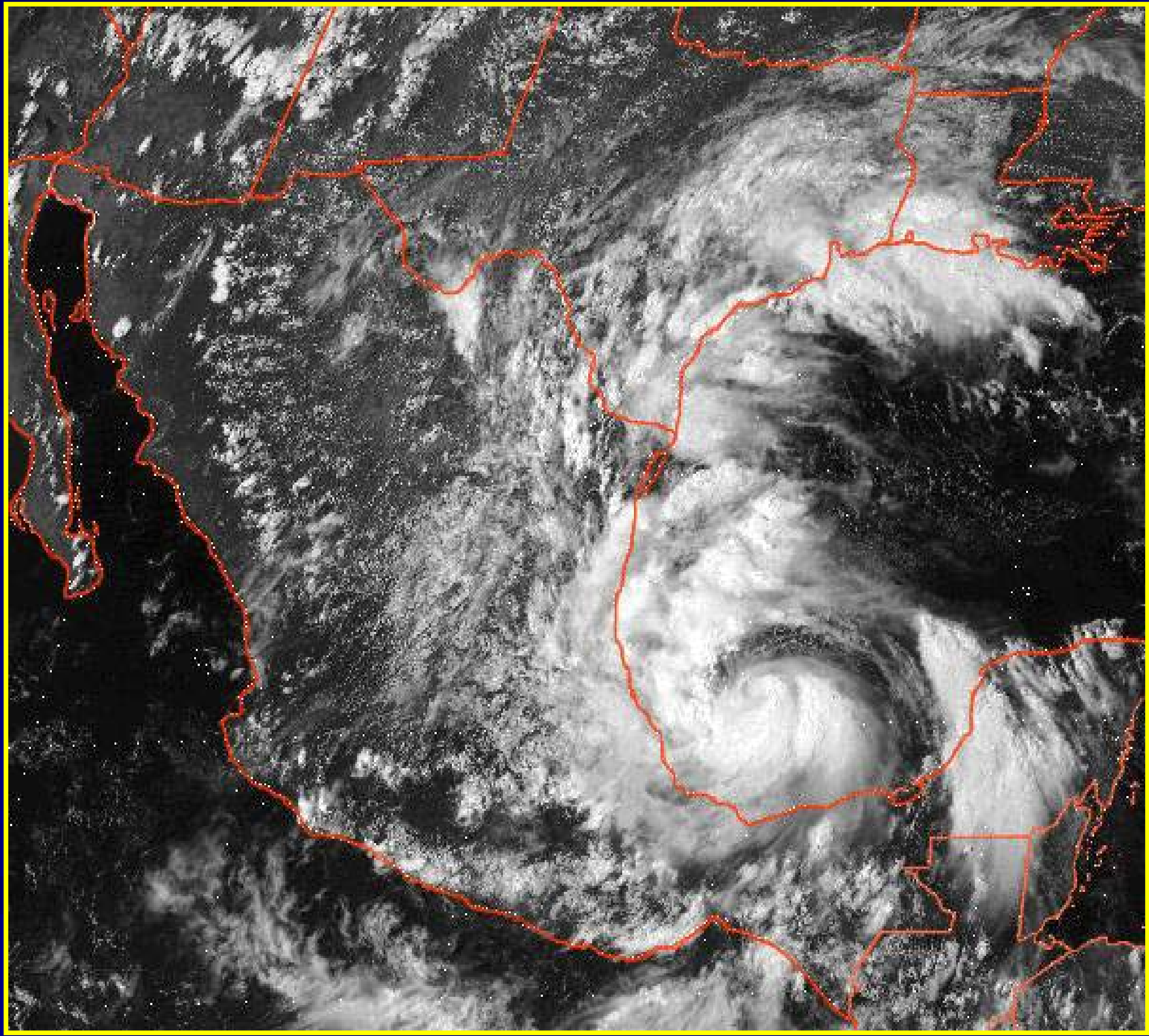
What about hurricanes?


LSU Earth Scan Lab
Coastal Studies Institute
GOES-8 GVAR Ch1
29 AUG 96 1745Z
Edouard
Fran
Gustav



Danny
Dolly
Status
Tropical Depression
Tropical Storm
Hurricane 1
7/24/97
7/20/97
7/16/97
8/25/96
8/19/96
35
30
25
20
15
105
100
95
90
85
80

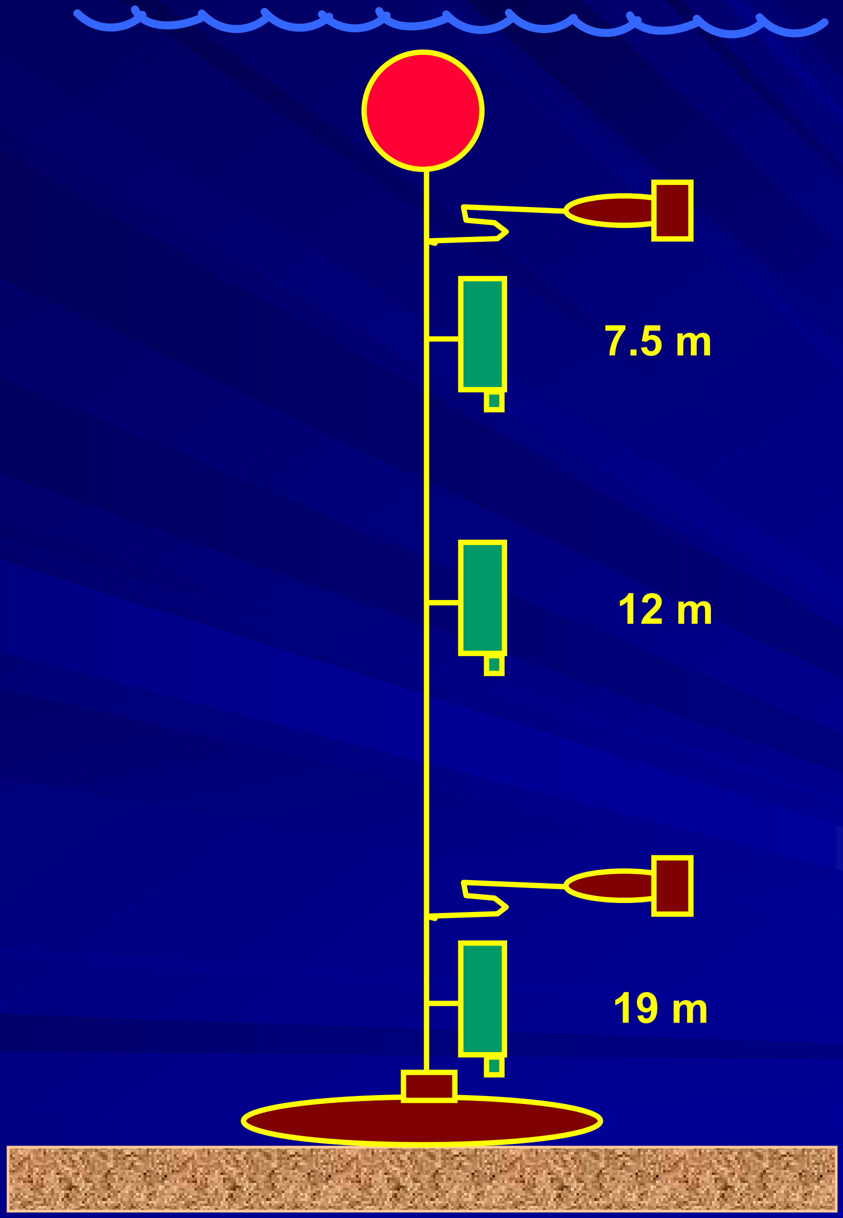
Hurricane Dolly 8/19/96 - 8/25/96



(Adapted from: http://www.amerwxccnpt.com/tropical/Dolly/dolly_9608222130_4km.jpg)

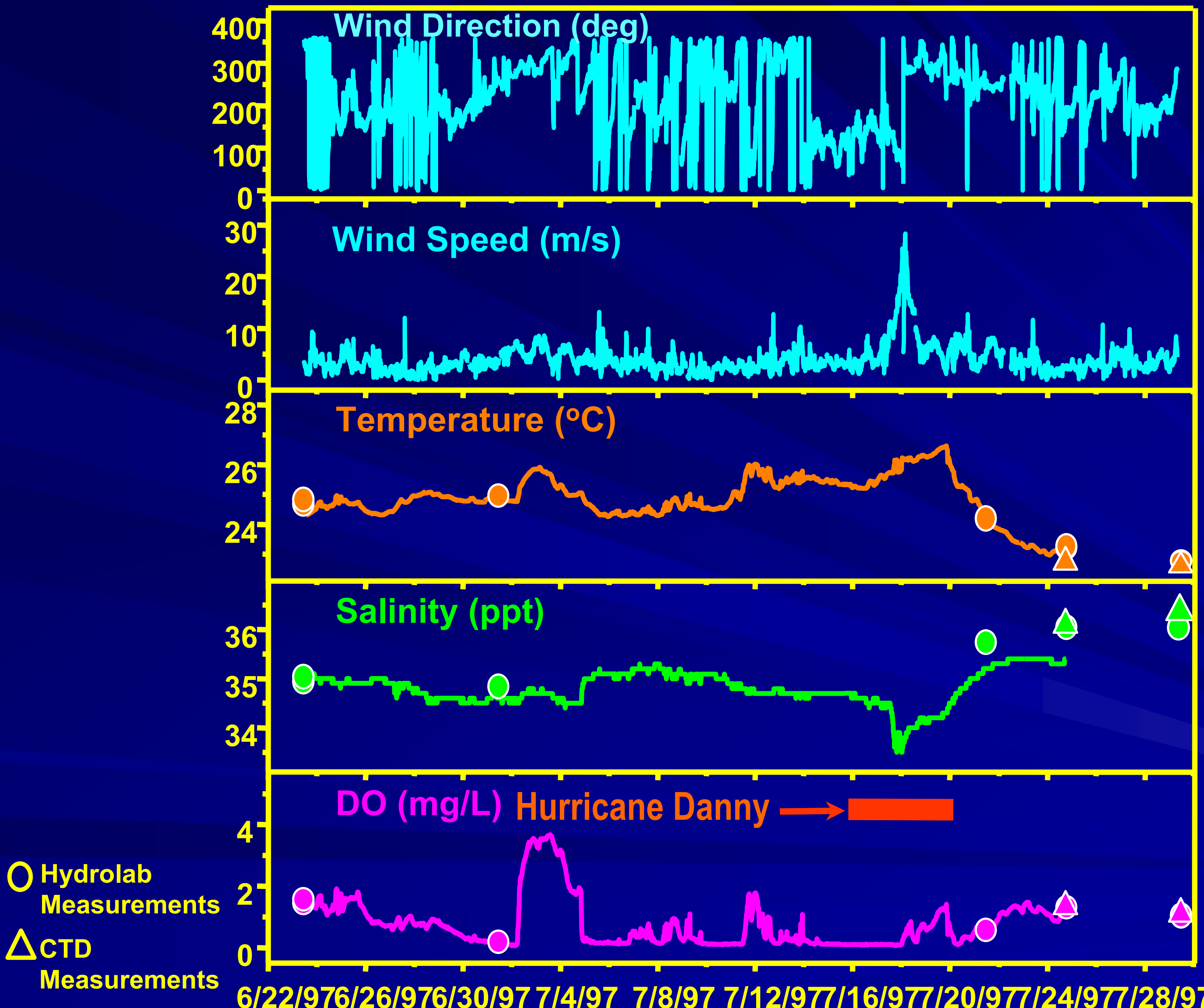
Hurricane Danny 7/16/97 - 7/26/97

Sampling design



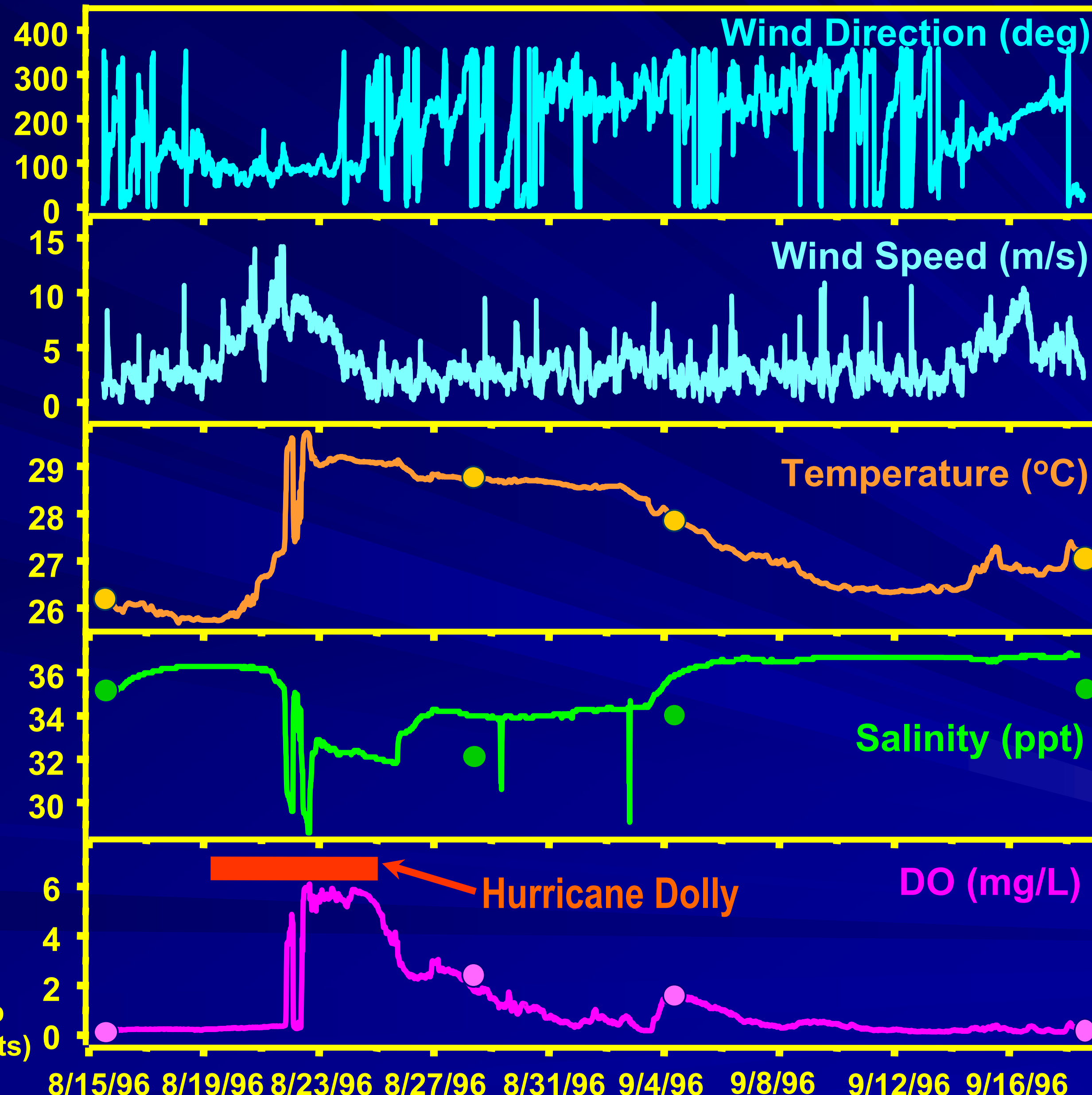
Source: D. Justic,
Coastal Ecology Institute,
Louisiana State University

Comparison of Continuous Record on station C6B (19.2 m) and Wind at Grand Isle from 6/23/97 - 7/28/97



Source: D. Justic,
Coastal Ecology Institute
Louisiana State Universit

Comparison of Continuous Record on station C6B (19.2 m) and Wind at Grand Isle from 8/15/96 - 9/20/96



(Hydrolab Measurements)

Source: D. Justic, Coastal Ecology Institute, Louisiana State University

Conclusions

- The ecosystem of the northern Gulf of Mexico appears to be highly sensitive to GCC.
- Model simulations suggest that an increase of 20% in the annual Mississippi River discharge, accompanied by a 4 ^{o}C increase in ambient water temperatures, which are likely under a 2XCO_2 scenario, may cause a 60% increase in the frequency of hypoxia.
- GCC could have major impacts on the abundance and diversity of benthic and epibenthic species, including those that are commercially important.

What can we do?

- Reduce MR nutrient load.
- Better management of fisheries resources to lessen negative impacts resulting from GCC.

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